Инжекеция-вольтаик режимда ишлайдиган биполяр транзисторларда бажарилган, ишчи кучланиши 0,7 В гача пасайган кичик қийматларда ишлайдиган (қуёш элементидан манба оладиган), параметрлари ҳароратга турғун мантиқий элементлар асосида таклиф этилган электрон қайта уланувчи ячейкалар ахборот технологиялари ва автоматлаштириш тизимларини қувват манбаининг ишлаш муддатини оширган.

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THERMAL TREATMENT OF RADIATION DEFECTS IN SILICON

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To restore the electrical properties of semiconductor materials and devices based on them after irradiation with nuclear particles, annealing of radiation defects (RD) is usually used. As a rule, annealing is understood as the thermal irreversible dissociation of a defect. In a broader sense, annealing covers the following processes: thermal dissociation of a defect; transfer of the entire marriage to the warehouse; separation of one of the components of the defect and irreversible drain; attachment of one of the components of the Frenkel pair to an existing defect [1].

The ultimate goal of studying the annealing of defects is to determine the activation energy of the annealing process and the frequency of jumps of the defect to the sink, as well as to elucidate the possible reactions of interaction between mobile and immobile defects at a given temperature. Sometimes it is also possible to determine the value of the defect destruction barrier if the pre-exponential factor v_0 is known in the expression:

$$v = v_0 \exp\left(-\frac{u_б}{kT}\right) \qquad (1)$$

where $u_б$ is the potential barrier that the diffusing particle overcomes; v is the average frequency of particle jumps.

In silicon, the annealing of simple RDs formed during the interaction of vacancies and interstitial silicon atoms with atoms of background and dopant impurities present in crystals has been studied in most detail.

The vacancy-oxygen complex (A-center, VO) is one of the main radiation defects in Si and introduces an acceptor level E_c – 0.17 eV into the band gap [2, 3]. When a vacancy is captured, the oxygen atom is displaced and located almost in the vacant site, without occupying a completely substituting position. It is offset from the center of the tetrahedral substitution position in the <100> direction and binds to two silicon atoms, forming Si-O_i-Si. The A center is usually annealed at 600 K with an activation energy of 1.3 eV [4]. It is assumed that during annealing, it migrates over the crystal as a whole with capture by other defects and the formation of more complex multi-vacancy oxygen centers of the V_2O_2 (Si-P_2), V_3O (Si-P_4) type. However, the electrical activity of these defects is only now beginning to be intensively investigated in connection with the need to increase the radiation resistance of nuclear radiation detectors. It is assumed that the energy levels of oxygen-vacancy complexes are located near the middle of the band gap.

Divacancies (V2) are annealed by diffusion in the crystal as a whole with an activation energy of ~ 1.3 eV and a frequency factor of ~ 10^{13} s^{-1} [5]. When studying the annealing of divacancies in silicon containing disordered regions, the authors observed three stages of annealing of divacancies in the temperature range 100–200°C with E_a = 1.0 eV; at (200–300)°C with E_a = 1.3 eV and (300–500)°C with E_a = 1.5 eV. This is due to different positions of divacancies: in the cluster core, in the space charge region (SCR) of the cluster, and in the conducting silicon matrix. The authors of [6] believe that, since divacancies are immobile at 150°C, their annealing can be described by recombination with mobile interstitial atoms.

The donor-vacancy complex (E-center) is annealed in the temperature range (80–250)°C, depending on the charge state, the type of dopant (P, As, Sb), and the tetrahedral covalent radius of the impurity atom. The activation energy of annealing of neutral E centers E_a = (0.94–1.46) eV depends linearly on the covalent radius (r): E_a = (15r–0.7) eV. A change in the neutral charge state to a single negative one leads to an increase in the annealing activation energy by ~0.3 eV. In n-Si doped with phosphorus, depending on the charge state of the defect, the annealing energy is 0.94 eV if the E-center is in a neutral charge state, and 1.25 eV if it is in a negative one. The mechanism of annealing of E-centers in silicon has not been precisely established, but both their migration and dissociation are possible.

The boron-vacancy complex (B-V) is unstable at room temperature according to EPR data. It follows from electrical measurements that the level E_V + 0.45 eV is annealed at a temperature of (360–500) K, however, the activation energy of its annealing is low: E_a = (0.42 ± 0.05) eV. Considering the value of the pre-exponential frequency factor $\nu_0 = (10^3 - 10^4)\ s^{-1}$, we can assume that the long-range migration of these RDs during annealing is captured by projectiles as the most probable.

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ОСОБЕННОСТИ СВОЙСТВ КРЕМНИЯ С ПОСЛЕДОВАТЕЛЬНО ЛЕГИРАВАННОГО ПРИМЕСНЫМИ АТОМАМИ ФОСФОРА И БОРА

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Примесных атомов B и P в решетке кремния создает бинарный элементарную ячейку большой научный и практический интерес. Si_2BP элементарная ячейка через ее параметры, формирование из нас на фундаментальных параметрах нового поколения кремния полупроводникового материала. Растворимость и малые коэффициенты